CLAIMS

1. A multi-layer piezoelectric element comprising:

a stack having an active portion constituted from at least one piezoelectric layer and a plurality of internal electrodes consisting of the first and the second internal electrodes placed one on another, the active portion being subjected to expansion and contraction in response to a voltage applied across the first internal electrode and the second internal electrode; and

external electrodes formed on two side faces of the stack, one of said external electrodes being connected to the first internal electrode and the other of said external electrodes being connected to the second internal electrode,

wherein each of the external electrodes has three or more layers including a first layer formed in contact with the side face of the stack and a second layer formed on the first layer.

2. The multi-layer piezoelectric element according to claim 1,

wherein a thickness of the first layer is 10 μm or less.

3. The multi-layer piezoelectric element according to claims 1 or 2,

wherein the first layer includes a metal oxide higher than the second layer.

4. The multi-layer piezoelectric element as in one of claims 1 to 3,

wherein a content of a metal oxide in an outermost layer of the external electrode is less than contents in any other layers of said three or more layers.

5. The multi-layer piezoelectric element according to claims 3 or 4,

wherein the metal oxide is a glass.

6. The multi-layer piezoelectric element as in one of claims 1 to 5,

wherein the stack has inactive layers made of a piezoelectric material located on both ends, the inactive layers including dispersed metal.

7. A multi-layer piezoelectric element comprising:

a stack having an active portion constituted from at least one piezoelectric layer and a plurality of internal electrodes consisting of the first and the second internal electrodes placed one on another, and inactive layers made of a piezoelectric material located on both ends of the active

portion, the active portion being subjected to expansion and contraction in response to a voltage applied across the first internal electrode and the second internal electrode; and

external electrodes formed on two side faces of the stack, one of said external electrodes being connected to the first internal electrode and the other of said external electrodes being connected to the second internal electrode,

wherein the inactive layers of the stack include dispersed metal.

8. The multi-layer piezoelectric element according to claims 6 or 7,

wherein said metal is at least one selected from a group consisting of Ag, Pd, Cu, Ca, Na, Pb and Ni.

9. The multi-layer piezoelectric element as in one of claims 6 to 8,

wherein an amount of said dispersed metal is in a range from 0.001 to 1.0% by weight in proportion to the inactive layer 12.

10. The multi-layer piezoelectric element as in one of claims 6 to 9,

wherein a thickness of the inactive layer is in a range from 0.1 mm to 2.0 mm.

11. The multi-layer piezoelectric element as in one of claims 6 to 10,

wherein said metal has the same composition as the internal electrode.

12. The multi-layer piezoelectric element as in one of claims 1 to 11,

wherein a metal compound in the internal electrode includes group 8 to group 10 metal and/or group 11 metal as the main components.

13. The multi-layer piezoelectric element according to claim 12,

wherein a proportion M1 (% by weight) of the group 8 to group 10 metal and a proportion M2 of the group 11 metal satisfy the relations $0 < M1 \leq 15$, $85 \leq M2 < 100$ and $M1 + M2 = 100$.

14. The multi-layer piezoelectric element according to claims 12 or 13,

wherein said the group 8 to group 10 metal is at least one selected from a group consisting of Ni, Pt, Pd, Rh, Ir, Ru and Os, and the group 11 metal is at least one selected from a group consisting of Cu, Ag and Au.

15. The multi-layer piezoelectric element as in one of claims 12 to 14,

wherein said the group 8 to group 10 metal is at least one selected from a group consisting of Pt and Pd, and the group 11 metal is at least one selected from a group consisting of Ag and Au.

16. The multi-layer piezoelectric element as in one of claims 12 to 14,

wherein said the group 8 to group 10 metal is Ni.

17. The multi-layer piezoelectric element as in one of claims 12 to 14,

wherein said group 11 metal is Cu.

18. The multi-layer piezoelectric element as in one of claims 12 to 17,

wherein one selected from a group consisting of oxide, nitride or carbide is added along with the metal compound in the internal electrode.

19. The multi-layer piezoelectric element according to claim 18,

wherein said oxide includes the perovskite type oxide of

$PbZrO_3$- $PbTiO_3$ as the main component.

20. The multi-layer piezoelectric element as in one of claims 1 to 19,

wherein the piezoelectric layer includes perovskite type oxide as the main component.

21. The multi-layer piezoelectric element according to claim 20,

wherein said piezoelectric layer includes the perovskite type oxide of $PbZrO_3$- $PbTiO_3$ as the main component.

22. The multi-layer piezoelectric element as in one of claims 1 to 21;

wherein grooves are formed between the second internal electrodes and the external electrodes on said one side face,

wherein grooves are formed between the first internal electrodes and the external electrodes on other side face,

wherein each of the grooves being filled with an insulating material that has Young's modulus lower than that of the piezoelectric material.

23. A method of manufacturing a multi-layer piezoelectric element comprising:

a step of forming piezoelectric layers on both end faces

of a green stack made by stacking green sheets of piezoelectric material and electrically conductive layers alternately;

a step of forming a metal layer on the piezoelectric layer; and

a step of firing the green stack having the piezoelectric layer and the metal layer formed thereon and then removing the metal layer.

24. The method of manufacturing a multi-layer piezoelectric element according to claim 23;

wherein the metal layer has a melting point not higher than 1.6 times the firing temperature of the multi-layer piezoelectric element.

25. The method of manufacturing a multi-layer piezoelectric element according to claims 23 or 24;

wherein the thickness of the metal layer is 5 mm or less.